(CLEAN VERSION) SPECIFICATION Optimal Surface Mitigated Multiple Targeting System (OSMMTS)

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1 Background of Invention

The concept of utilizing an array of sensors to calculate a position report is well represented in the prior art. Patents as far back as Koeppel, #2,855,595, October 1958, have utilized "a plurality of reference points" (this expression is used in Heldwein, et al., #4,229,737, October 1980) as a basis for determining an object's position. Additional references to arrays of sensors and reference points for locating a "vehicle" or "transceiver" include Drouilhet, et al., #5,570,095, October 1996; Nilsson, #4,524,931, June 1985; Chisholm, #3,412,399, November 1968, and Fletcher, et al., #3,153,232, October 1964. In fact, Jandrell, #5,526,357, June 1996, as a continuation of #5,365,516, August 1991, extends the use of the sensor array to a "two-way message delivery system for mobile resource management, "including the use of "a control center containing means for determining the location of the polled transponder." In a related track, a "method and system for highly accurate navigation of ships and aircraft" using "transmitted wave energy at regular intervals" was described in Beasley, #4,024,383, May 1977. In addition, the use of "multilateration," i.e., the use of multiple sensors to calculate positions from transmitted signals, is used in Jandrell (cited above), Saito, et al, #4,673,921, June 1987; Fuller, et al., #3,646,580, February 1972; and as far back as Ross, #2,972,742, February 1961.

A recent development found in Smith, et al., #6,094,169, July 2000, includes a "correction method" for multilateration "based on a signal from secondary radar." Furthermore, modern, widely used systems such as GPS (Global Positioning Satellites), LORAN (Long-range Radio Navigation), and Lo-Jack use differential arrival times at "a plurality of reference points" to produce their position reports, with claims of "excellent" accuracy given proximity constraints.

However, none of these existing patents, with the information found collectively in the prior art, adequately addresses four practical, critical issues that

are completely solved by the OSMMTS. The prior art either completely ignores these issues, such as in the cited pre-1980 patents, or only briefly touches on the issues without providing objective, justifying documentation. The four critical issues left unsatisfied in the prior art may be called the Issues of Likelihood of Accuracy, Maintenance, Universality, and Optimality.

The OSMMTS completely addresses these issues as follows:

1. 1. All data transmissions, from whatever source or through whichever medium, are subject to error, whether through corrupted transmission, fraudulent use, or aberrant conditions. When information is received at a sensor, data corruption in some sense is always possible, as well as abhorrent signals from reflections, or even from intentional false data inserted to deceive the sensing equipment. The extent and efficiency with which a method or system addresses the potential presence of corrupted data determines how useful that method or system may be. This is the Issue of Likelihood of Accuracy, i.e., how likely are the position reports accurate and to what extent can it detect "false" or "impossible" or even "unlikely" data? Can the method or system consistently produce a position report within a given distance, say, 95% of the time over, say, a 24-hour period using only "valid" data? This issue is touched upon in Smith, et al., #6,094,169, July 2000, without quantification, by use of a secondary radar system, which may or may not be applicable outside of aviation uses, and which may or may not be as accurate as the original position report. Furthermore, Beasley, #4,024,383, May 1977, claims to produce a "highly accurate" report, again without justification. The prior art otherwise contains very little objective quantification concerning the Issue of Likelihood of Accuracy, if it is addressed at all. Without quantifying and controlling the likelihood of an inaccurate position report in a meaningful and automatic manner, the method or system under consideration cannot be trusted to produce useful information.

   The OSMMTS contains non-obvious, novel, and critically useful analytical algorithms and data structures that quantify the Likelihood of Accuracy of each position report individually at the time of calculation, and collectively as further processing continues. Furthermore, data that has been corrupted or intentionally altered is sensed automatically by the analytical methods, thus preventing this data from corrupting the position report. This important OSMMTS feature ensures that any given position report may be trusted, in the sense that the probability that it represents a significantly incorrect report may be made arbitrarily small by adjusting the calculation parameters in the analytical methods.

2. All electrical and mechanical equipment, such as the "array of sensors "or "plurality of reference points" mentioned in the prior art, is subject to malfunction, sometimes manifested as catastrophic failure, but more often as a slow, cumulative wearing out of control. The ability of a method or system to sense when a sensor, or group of sensors, has reached a point

where its cumulative wear is now producing significantly erroneous data, is critical to the usefulness of such a method or system. If one cannot tell when the system is reporting garbage, how can its output be trusted? This is the Issue of Maintenance. The prior art is silent on the integration of concurrent maintenance of a target reporting system. No mention is made in the prior art concerning a method or system that can sense during its operation when a sensor has significantly wore out of control.

The OSMMTS contains analytical methods, data structures, and an operational policy for discerning during its operation when a sensor has significantly wore out of control or has failed outright. Each position report is evaluated for consistency and likelihood of applicability to detect when sensors may be wearing out of control, or when "impossible" data has been received. This ongoing surveillance of the data quality involved in the calculations is automatically applied to the reporting subsystem without the need for outside, primary monitoring. This vitally useful and novel OSMMTS feature is not addressed in the prior art.

3. The pertinent prior art that utilizes an array of sensors to calculate a position report always refers to a context specific to the patent. Beasley, #4,024,383, May 1977, refers to "ships and aircraft," while Jandrell, #5,526,357, June 1996, specifically mentions "mobile resource management" with respect to where equipment are at a given moment. And Drouilhet, et al., #5,570,095, October 1996, refers to "vehicles," meaning equipment that physically resembles an automobile or cart. Since there is always a particular context in which the patent is described, the prior art fails to address the - Issue of Universality, where the methods and system in question work equally well regardless of implementation context. For example, the OSMMTS error-bounding methods work equally well when the sensors are microscopic entities in an animal's bloodstream, or detecting aircraft at great distances, or in tracing vortex changes in a tornado. The OSMMTS is context neutral, or context independent, which the prior art does not claim, as it could not support such a claim.

4. The final feature of the OSMMTS not addressed by the prior art is the Issue of Optimality. The prior art makes no attempt to optimize its performance from priori information. For example, Smith, et al., #6,094,169, July 2000, refers to an "error correction" through a signal from a secondary radar interrogation (with clear context to a ground-based radar system most commonly used in aviation surveillance). However, the extent to which the "error" is "corrected" due to characteristics of the secondary radar system is not addressed, nor even mentioned in the preferred embodiment. In other words, is the error correction due to Radar System #1 better than that from the use of Radar System #2, and if so, by how much, and why? And why is such a correction an improvement on the original position report?

   The OSMMTS addresses the Issue of Optimality by defining objective, an-

alytical methods for optimizing the performance of the OSMMTS before any data is collected, or before any calibration is needed. This distinguishes the OSMMTS from the prior art by minimizing the natural introduction of error into position calculations through numerical optimization algorithms.

5. Furthermore, notwithstanding the Ito, #6,108,556, August 2000, prior art claim of analytically calculating a position report, Ito, #6,108,556, August 2000, does not contain specific analytical calculation formulae, nor step-by-step instructions for performing said calculation, as do the OSMMTS claims. These specific analytical calculation formulae (found in Claims 1 (currently amended), 4 (currently amended), and 5 (currently amended)) cannot be reasonably anticipated by Ito, #6,108,556, August 2000, nor any other prior art. In addition, the explicit use of specific analytical calculation formulae in the OSMMTS is clearly novel, non-obvious, and useful, not only in providing Target Position Reports, Error Likelihood Ellipses, Likelihood of Accuracy measures, Demerit System counts, and various mitigations and optimizations, but also towards implementing the OSMMTS. These facts thereby establish the OSMMTS as a patentable invention.

2 Summary of Invention

The purpose of the Optimal Surface Mitigated Multiple Targeting System (OSMMTS) is to encapsulate the analytical methods and processing system necessary to produce, in real time, an error-bounded, self-monitoring and self-adjusting, likelihood-based Target Position Report for arbitrarily many self-identifying targets in a two-dimensional grid. Each target sends identifying information to an array of sensors strategically placed in its vicinity to maximize the likelihood that the system will produce a position report as accurately and precisely as possible. The OSMMTS uses analytical and ad-hoc mitigation and optimization techniques to reduce the error bounds on the Target Position Report to a practical minimum. The OSMMTS consists of the analytical methods, construct guidelines, quantification methods, mitigation and optimization techniques, and programming details for implementing the system in hardware and software in such a manner as to allow Target Position Report calculations arbitrarily frequently.

3 Brief Description of Drawings

The acronyms used herein are defined in the Detailed Description Section.

Fig. 1 depicts the cyclic nature of the signal timing used in mitigations for reflections and other optimizations. During PCPU cycles 0 through 10^{p_1}, inclusive, the system is in the Receive phase; during PCPU cycles 10^{p_1} through 10^{p_2}, not including the former but including the latter, the system is in the

Query phase; during PCPU cycles 10^{p_2} through 10^{p_3}, not including the former but including the latter, the system is in the Confirm phase; during PCPU cycles 10^{p_3} through 10^{p_4}, not including the former but including the latter, the system is in the Process phase; during PCPU cycles $10^{p_4}, 10^{p_5}$, not including the former but including the latter, the system is in the Report phase; and from PCPU cycles 10^{p_5} to the end of the OSMMTS cycle, not including either the former or the latter, the system is in the Sync phase. This cycle is repeated every $\frac{10^n}{\rho}$ PCPU cycles in a 10^n Hz PCPU, where there are ρ OSMMTS cycles per second. The particular values of $n, p_1, p_2, p_3, p_4, p_5$, and ρ are implementation dependent.

Fig. 2 depicts the data processing interaction between the Principal Application Specific Integrated Circuit, the related databases, and the Surface Detection Units. This interaction facilitates the production of the Target Position Report.

4 Detailed Description

The OSMMTS interface consists of one Principal Application Specific Integrated Circuit (ASIC) Central Processing Unit (CPU), generically referred to as the PCPU, a set of (at least four) remote sensing Surface Detection Units (SDU's) that send information to the PCPU, and a database of statically stored data that the PCPU accesses for parameter data, algorithm exceptions, and other information, which are used to produce the Target Position Report, as well as supporting reports as the implementation determines (see Fig. 2). The PCPU, SDU's, and any database systems must be coordinated on and agree with an absolutely maintained time system, accurate to at least twice the precision of the anticipated Target Position Report.

A Target Position Report (TPR) is generated whenever a SDU sends a stream of timing information to the PCPU. Since different SDU will send information at different times about the same target, an absolute timing schedule must be used to ensure valid comparison of timing data from the SDU set.

A Target $\mathbf{T}$ may only initiate a signal to the SDU set when $t = 0 \bmod \xi$, where $\xi = \frac{10^n}{\rho}$ PCPU cycles in a 10^n Hz PCPU, where there are ρ OSMMTS cycles per second. For example, if a target sends a signal to the SDU set every half second, then $\rho = 2$, and $\xi = \frac{10^n}{2} = \frac{10^n}{10^{\log_{10} 2}} = 10^{n-\log_{10} 2}$ PCPU cycles.

The Effective Range of the OSMMTS System is the maximum time for this receive/query/confirm period. It measures the farthest a target may be away from the closest qualifying set of SDU's and still be detected by the system.

A complete Signal Period, $\xi = \frac{10^n}{\rho}$ PCPU cycles in a 10^n Hz PCPU, consists of six Phases, each encompassing an interaction between the PCPU, the SDU set, and the databases (see Fig. 1).

The Phases are:

1. Receive, during which the PCPU receives the detected signal information from the SDU set. This phase must last as long as the effective range, plus overhead time for communications between the SDU set and the PCPU. The information passed during this phase consists of:

   (a) SDU ID
   (b) Target ID
   (c) Time Of Signal Detection.

   The SDU and Target ID are static codes used throughout all phases and signal periods. If either the SDU ID or the Target ID changes during a signal period, it must be through a formal change management process incorporated into the particular implementation of the OSMMTS System. It shall be the responsibility of the OSMMTS implementation to ensure that changing SDU ID and/or Target ID are linked properly for inference purposes. The Time of Signal Detection is relative to the common absolute timing mechanisms in the OSMMTS System.

2. Query, during which the PCPU queries the sending SDU for a confirmation code to ensure communication integrity. If the confirmation code sent by the SDU is not correct (see the next phase), the PCPU queries the SDU again for the proper confirmation code. This is repeated up to a tunable number of iterations. If no correct confirmation code is received in the allotted time, the SDU is deactivated.

3. Confirm, during which the PCPU receives and processes the confirmation code sent by the SDU. It is during this phase that any required re-transmissions are also requested, received, and disposed.

4. Process, during which all calculations are completed to produce the Target Position Report, and subsequent reports for evaluation, quantification, and adjustment purposes.

5. Report, during which the Target Position Report and supporting information are made available on output channels, and during which any auxiliary communications with the SDU's are completed.

6. Sync, during which no processing activity is scheduled. This is useful when coordinated processing activities require synchronized signal periods.

One signal period begins when the previous one ends. The sync phase may be used to coordinate any overhead processing issues to implement this requirement.

The Error Likelihood Ellipse (ELE) is the standardized elliptical region that represents the highest likelihood of the actual position of the target. A special constant is used to form the ellipse, called the Standardized Elliptical Constant (SEC).

A TPR is said to be accurate if the calculated position of the target is inside the ELE for the same data as was used to calculate the TPR. The SEC determines the likelihood of this event.

Any calculation algorithm used to produce a set of numerical values intermediate and inferior to the TPR is called an analytical step.

An analytical step is called a mitigation if it is taken before the arrival time data $\{t_1, t_2, \ldots, t_k\}$ are collected.

An analytical step is called an optimization if it occurs after the arrival time data $\{t_1, t_2, \ldots, t_k\}$ are collected.

The purpose of mitigation steps is to reduce the error variances.

The purpose of optimization steps is to increase the likelihood of an accurate TPR.

An irregularly occurring, non-analytical step taken at any time to accomplish the same goals as mitigation and optimization is called ad-hoc.

The collection of ad-hoc, mitigation, or optimization steps taken in an implementation of the OSMMTS is called the system's containment policies, and referred to individually as a system containment policy.

The OSMMTS Demerit System is an ad-hoc containment policy that acts simultaneously as a mitigation and an optimization. Under this system, the three SDU's chosen to calculate the TPR are those three that are most likely to produce the "best" TPR based on past performance (thereby making it a optimization step), by way of reducing the variability of the utilized data (thereby making it a mitigation step).

Suppose there are n-many SDU's, however, only $k \leq n$ many receive a signal within the reception window. There are $\binom{n}{k}$-many combinations of SDU's, and $\binom{k}{3}$-many combinations of the k-many that receive the signal taken three at a time. Each SDU has three values associated with it at the beginning of each processing cycle, namely its non-negative Demerit Count, its positive History Total, and its possibly null Boolean Confirmation Value. At the beginning of all processing, the demerit count for each SDU will be zero, the history total will be one, and the confirmation value will be null. The confirmation value at the beginning of the processing cycle is determined by its observed value during the confirmation cycle. At the end of a processing cycle, the demerit count and history total are determined by the steps described in Claim 5(b) (currently amended), and the confirmation value is set back to null.

See also the *The Optimal Surface Mitigated Multiple Targeting System Patent Application Technical Documentation* memorandum referred to in the Information Disclosure Statement for a complete analytical description and derivation of the OSMMTS methods and processes.

5 Claims

1. A method for

   (a) Analytically calculating a Target Position Report (x_0, y_0) for arbitrarily many self-identifying targets in a two-dimensional grid according to the algorithm, whereas given the speed of signal propagation c, Surface Detection Unit positions (x_1, y_1), (x_2, y_2), and (x_3, y_3), and observed arrival time data $\{t_1, t_2, t_3\}$ at Surface Detection Unit positions (x_1, y_1), (x_2, y_2), and (x_3, y_3), then

      i. Calculate $f_1 = t_1 - t_2$ and $f_2 = t_1 - t_3$, then

      ii. Calculate $d_1 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ and $d_2 = \sqrt{(x_1 - x_3)^2 + (y_1 - y_3)^2}$, however,

      iii. When $y_1 \neq y_2$, $y_1 \neq y_3$, and $d_i > |f_i|\, c$, for $i = 1, 2$, then

         A. Calculate $m_1 = -\left(\frac{x_2 - x_1}{y_2 - y_1}\right)$, then

         B. Calculate $m_2 = -\left(\frac{x_3 - x_1}{y_3 - y_1}\right)$, then

         C. Use $b_1 = \frac{f_1 c \sqrt{4\kappa + (f_1 c)^2} + \left(x_2^2 - x_1^2\right) + \left(y_2^2 - y_1^2\right)}{2(y_2 - y_1)}$, then

         D. Use $b_2 = \frac{f_2 c\left((f_1 + f_2)c + \sqrt{4\kappa + (f_1 c)^2}\right) + \left(x_3^2 - x_1^2\right) + \left(y_3^2 - y_1^2\right)}{2(y_3 - y_1)}$, then

         E. Solve

$$\kappa = \frac{d_1^2 - (f_1 c)^2}{2} + \left\{ \begin{array}{l} \left(x_1 - \left(\frac{b_2 - b_1}{m_1 - m_2}\right)\right)\left(x_2 - \left(\frac{b_2 - b_1}{m_1 - m_2}\right)\right) \\ + \left(y_1 - \left(m_1\left(\frac{b_2 - b_1}{m_1 - m_2}\right) + b_1\right)\right)\left(y_2 - \left(m_1\left(\frac{b_2 - b_1}{m_1 - m_2}\right) + b_1\right)\right) \end{array} \right\}$$

         for κ; call this value κ_0; then

         F. Evaluate b_1 and b_2 with $\kappa = \kappa_0$; call these values β_1 and β_2, respectively, then

         G. Calculate

$$(x_0, y_0) = \left(\frac{\beta_2 - \beta_1}{m_1 - m_2}, m_1\left(\frac{\beta_2 - \beta_1}{m_1 - m_2}\right) + \beta_1\right)$$

         however,

      iv. When $y_1 = y_2$, $y_1 \neq y_3$, and $d_i > |f_i|\, c$, for $i = 1, 2$, then

         A. Use $r_1 = \frac{\pm f_1 c \sqrt{4\kappa + (f_1 c)^2} + \left(x_2^2 - x_1^2\right)}{2(x_2 - x_1)}$, then

         B. Use $r_2 = \frac{1}{2(y_3 - y_1)} \left(\begin{array}{l} f_2 c\left((f_1 + f_2)\, c \pm \sqrt{4\kappa + (f_1 c)^2}\right) + \left(x_3^2 - x_1^2\right) + \left(y_3^2 - y_1^2\right) \\ - \left(\pm f_1 c \sqrt{4\kappa + (f_1 c)^2} + \left(x_2^2 - x_1^2\right)\right)\left(\frac{x_3 - x_1}{x_2 - x_1}\right) \end{array} \right)$,

         then

C. Solve

$$\kappa = \frac{d_1^2 - (f_1 c)^2}{2} + (x_1 - r_1)(x_2 - r_1) + (y_1 - r_2)(y_2 - r_2)$$

for κ; call this value κ_0, then

D. Evaluate r_1 and r_2 with $\kappa = \kappa_0$; call these values γ_1 and γ_2, respectively, then

E. Assign $(x_0, y_0) = (\gamma_1, \gamma_2)$, however,

v. When $y_1 \neq y_2$, $y_1 = y_3$, and $d_i > |f_i| c$, for $i = 1, 2$, then

A. Use $r_1 = \frac{f_2 c^2 (f_1 + f_2) \pm \sqrt{4\kappa_0 + (f_1 c)^2} + (x_3^2 - x_1^2)}{2(x_3 - x_1)}$, then

B. Use $r_2 = \frac{1}{2(y_2 - y_1)} \left(\begin{array}{l} \pm f_1 c \sqrt{4\kappa_0 + (f_1 c)^2} + (x_2^2 - x_1^2) + (y_2^2 - y_1^2) \\ - \left(f_2 c \left((f_1 + f_2) c \pm \sqrt{4\kappa_0 + (f_1 c)^2} \right) + (x_3^2 - x_1^2) \right) \left(\frac{x_2 - x_1}{x_3 - x_1} \right) \end{array} \right)$,

then

C. Solve

$$\kappa = \frac{d_1^2 - (f_1 c)^2}{2} + (x_1 - r_1)(x_2 - r_1) + (y_1 - r_2)(y_2 - r_2)$$

for κ; call this value κ_0, then

D. Evaluate r_1 and r_2 with $\kappa = \kappa_0$; call these values γ_1 and γ_2, respectively, then

E. Assign

$$(x_0, y_0) = (\gamma_1, \gamma_2)$$

2. A system, comprising

(a) one Principal Application Specific Integrated Circuit Central Processing Unit that implements said method of Claim 1 (currently amended), and

(b) a set of (at least three) Surface Detection Units that send information to said Principal Application Specific Integrated Circuit Central Processing Unit, and

(c) a network of databases of statically stored data that said Principal Application Specific Integrated Circuit Central Processing Unit uses to produce said Target Position Report.

3. A system of Claim 2 (currently amended), wherein said information sent from said Surface Detection Units to said Principal Application Specific Integrated Circuit Central Processing Unit is uniquely coded in a format that

(a) said Principal Application Specific Integrated Circuit Central Processing Unit uses to identify said communicating Surface Detection Unit, and

(b) said network of databases of statically stored data uses to update its data.

4. A method of Claim 1 (currently amended), wherein said step of calculating said Target Position Report provides

   (a) an Error Likelihood Ellipse, given by those points (x_0^*, y_0^*), such that

$$\left(\frac{x_0^* - x_0}{1 - \frac{m_2}{m_1}}\right)^2 + \left(\frac{y_0^* - y_0}{m_1 - m_2}\right)^2 = R$$

where $(m_1 - m_2)(x_0^* - x_0)$ is distributed as $M_2(t_1, t_2, t_3)$, and $\left(1 - \frac{m_2}{m_1}\right)(y_0^* - y_0)$ is distributed as $M_2(t_1, t_2, t_3)$, and $m_1 = -\left(\frac{x_2 - x_1}{y_2 - y_1}\right)$ and $m_2 = -\left(\frac{x_3 - x_1}{y_3 - y_1}\right)$, and $M_2(t_1, t_2, t_3)$ is the probability distribution given by the difference between two independent $M_1(t_1, t_2, t_3)$ distributions, and for which, in turn, $M_1(t_1, t_2, t_3)$ is a probability distribution given by $\frac{1}{2(y_3 - y_1)}\left(\mp f_2 c\sqrt{2\left(\frac{d_2^2 - (f_2 c)^2}{(1 - \cos\theta_0^*)}\right) + (f_2 c)^2} \pm \xi_2\sqrt{2\left(\frac{d_2^2 - \xi_2^2}{(1 - \cos\theta_0)}\right) + \xi_2^2}\right)$ (where the choice of sign depends on the relationships between (x_1, y_1), (x_2, y_2), and (x_3, y_3), as in Claim 1 (currently amended)), and where $\xi_2 = (f_2 - (\varepsilon_1 - \varepsilon_3))\, c$ is distributed as $N(f_2 c, 2c^2\sigma^2)$ (the standard normal distribution with σ being the standard deviation of the errors occurring in the system described in Claim 3(b) (currently amended)), and η is distributed as $M_0(t_1, t_2, t_3)$, where $M_0(t_1, t_2, t_3)$ is a probability distribution given by $\cos\theta_0^* - \cos\theta_0$, where θ_0 is the (acute) angle of intersection between the lines of intersection L_1 and L_2, where

$$L_1 : \begin{cases} x = \dfrac{\pm f_1 c\sqrt{4\kappa_1 + (f_1 c)^2} + \left(x_2^2 - x_1^2\right)}{2(x_2 - x_1)}, & y_1 = y_2 \\ y = -x\left(\frac{x_2 - x_1}{y_2 - y_1}\right) + \left[\dfrac{\pm f_1 c\sqrt{4\kappa_1 + (f_1 c)^2} + \left(x_2^2 - x_1^2\right) + \left(y_2^2 - y_1^2\right)}{2(y_2 - y_1)}\right], & y_1 \neq y_2 \end{cases}$$

and

$$L_2 : \begin{cases} x = \dfrac{f_2 c\left((f_1 + f_2)c \pm \sqrt{4\kappa_1 + (f_1 c)^2}\right) + \left(x_3^2 - x_1^2\right)}{2(x_3 - x_1)}, & y_1 = y_3 \\ y = -x\left(\frac{x_3 - x_1}{y_3 - y_1}\right) + \left[\dfrac{f_2 c\left((f_1 + f_2)c \pm \sqrt{4\kappa_1 + (f_1 c)^2}\right) + \left(x_3^2 - x_1^2\right) + \left(y_3^2 - y_1^2\right)}{2(y_3 - y_1)}\right], & y_1 \neq y_3 \end{cases}$$

(with corresponding values for θ_0^*), where κ_1 is the value of κ_0 found in Claim 1(a)(iii)(E) (currently amended), or Claim 1(a)(iv)(C) (currently amended), or Claim1(a)(v)(C) (currently amended), when combinations of $\{(x_1, y_1), (x_2, y_2)\}$ (for L_1) and $\{(x_1, y_1), (x_3, y_3)\}$ (for

L_2) are used, and the Standardized Elliptical Constant R is defined by

$$R = \frac{(m_1 - m_2)(x_0^* - x_0)^2 + \left(1 - \frac{m_2}{m_1}\right)(y_0^* - y_0)^2}{\left(\frac{(m_1-m_2)^2}{m_1}\right)}$$

and which provides

(b) a Likelihood of Accuracy measure of said Target Position Report using said Error Likelihood Ellipse, calculated by the area of

$$(m_1 - m_2)(x_0^* - x_0)^2 + \left(1 - \frac{m_2}{m_1}\right)(y_0^* - y_0)^2 = \frac{(m_1 - m_2)^2}{m_1} R$$

with all terms as defined in Claim 4(a) (currently amended).

5. A method of Claim 1 (currently amended), wherein said step of calculating said Target Position Report uses

   (a) arrival times at a said set of Surface Detection Units, and

   (b) a Demerit System, implemented for each processing cycle, and for each of the $\binom{k}{3}$-many combinations, the following steps determine the end-of-processing-cycle demerit counts and history totals, whereas

      i. Set the likelihood value λ, and
      ii. Eliminate those τ_0-many combinations of signal receiving Surface Detection Units that are collinear, and
      iii. Eliminate those τ_1-many combinations of signal receiving Surface Detection Units that do not all
         A. have positive history totals, and
         B. have received a confirmation during the Confirm phase of the current processing cycle, and
      iv. The Surface Detection Units involved in the $(\tau_0 + \tau_1)$-many combinations eliminated under the previous two steps are called deficient for the current processing cycle, where this designation is removed at the beginning of a new processing cycle, and
      v. Among the remaining qualifying combinations, choose the combination of three Surface Detection Units that collectively have the minimal sum of demerits, and
      vi. In case of a tie in the previous step, use the combination with the largest history sum, whereas in case of a further tie, choose the combination with the smallest individual demerit count, whereas in case of a last tie, randomly choose uniformly among the finalists, whereas the combination so chosen is called the calculating combination, and the Surface Detection Units involved are called the elected Surface Detection Units, then increment the history total by 1 for each elected Surface Detection Unit, and

vii. Subtract two demerits from the count for each elected Surface Detection Unit, recalling the demerit count for an Surface Detection Unit cannot become negative, and

viii. Calculate the Target Position Report using the calculating combination, and

ix. Calculate the λ-Error Likelihood Ellipse for the calculating combination, which is the Error Likelihood Ellipse described in Claim 4(a) (currently amended) that has a Likelihood of Accuracy value (found in Claim 4(b) (currently amended)) of λ, and

x. Calculate the $\binom{k}{3} - (\tau_0 + \tau_1)$-many Target Position Reports for all other qualifying combinations, whereas each of these Target Position Reports is called an Alternate Position Report, and

xi. For each Alternate Position Report calculated in the previous step, if the Alternate Position Report falls outside the λ-Error Likelihood Ellipse, then add one demerit to the count for each Surface Detection Unit involved in the Alternate Position Report, and

xii. For each Alternate Position Report referred to in the previous step, if the Alternate Position Report falls inside or on the λ-Error Likelihood Ellipse, then subtract one demerit from the count for each Surface Detection Unit involved in the Alternate Position Report, recalling the demerit count for a Surface Detection Unit cannot become negative, and

xiii. Add one demerit for each Surface Detection Unit that does not report a positive confirmation, and

xiv. When the demerit count for an Surface Detection Unit exceeds the Warning Threshold, send an alert to report a frequently deficient Surface Detection Unit, and

xv. When the demerit count for an Surface Detection Unit exceeds the Terminal Threshold, shut down communication with the Surface Detection Unit and do not consider it further (by setting its history total to zero) until explicitly reset, and also send an alert to report a failed Surface Detection Unit, and perform

xvi. These steps in addition to the disabling of an Surface Detection Unit if proper query responses are not confirmed during the receive phase, and

(c) a containment policy to maximize said Likelihood of Accuracy, which consists of calculating

$$\frac{d_{\min}}{c} = \frac{1}{c} \min_{0 \le s \le 1} \{d_1(s) + d_2(s)\} \text{ and } \frac{d_{\max}}{c} = \frac{1}{c} \min_{0 \le s \le 1} \{d_1(s) + d_2(s)\}$$

$$\text{subject to}$$

$$d^2(s) = d_1^2(s) + d_2^2(s) - 2d_1(s)\, d_2(s)\, \gamma(s)$$

where

$$d_1(s) = \sqrt{\left((x_1 - x_l) - s(x_r - x_l)\right)^2 + \left((y_1 - y_l) - s(y_r - y_l)\right)^2}$$

and

$$d_2(s) = \sqrt{((x_0 - x_l) - s(x_r - x_l))^2 + ((y_0 - y_l) - s(y_r - y_l))^2}$$

and comparing $\frac{d_{\min}}{c}$ and $\frac{d_{\max}}{c}$ to any signal arrival time t_i at a particular Surface Detection Unit, and if

$$t_i < \frac{d_{\min}}{c} \text{ or } \frac{d_{\max}}{c} < t_i$$

then all Target Position Reports associated with the particular Surface Detection Unit are rejected, and a new Target Position Report is calculated using the next highest priority qualifying combination of Surface Detection Units, whereas this cycle continues until a Target Position Report is accepted or the qualifying combinations of Surface Detection Units are depleted.

6. A system of Claim 2 (currently amended), wherein said Surface Detection Units are

   (a) physically distinct from said Principal Application Specific Integrated Circuit Central Processing Unit, and

   (b) coordinated to a master timing clock administered by said Principal Application Specific Integrated Circuit Central Processing Unit, and

   (c) optimally located to maximize said Likelihood of Accuracy, which consists of placing the Surface Detection Units

      i. where the geometrically connected unit positions form a convex hull, and

      ii. in such a way that the convex hull should cover as much of the possible target locations as possible, and

      iii. in such a way that no three units are collinear, and

      iv. so that no two units have the same x-value or y-value, as viewed in a coordinate grid, and

      v. to maximize the likelihood that $d_i > |f_i| c$, for all i, as the terms are defined in Claim 1(a) (currently amended).

7. A method of Claim 1 (currently amended), wherein said step of calculating said Target Position Report is

   (a) performed on one set of incoming data before another set of said incoming data is processed, whereas the calculations are performed in real time, and

   (b) self-monitoring as to accuracy, and

   (c) self-adjusting as to accuracy, and

   (d) likelihood-based as to accuracy, and

(e) error bounded, whereas said Likelihood of Accuracy may be made arbitrarily large by adjusting the characteristics of said set of Surface Detection Units.

8. A method of Claim 1 (currently amended), wherein

   (a) said Target Position Reports may be calculated arbitrarily frequently, and

   (b) said step of Claim 5(c) (currently amended) of using containment policies to maximize said Likelihood of Accuracy is implemented analytically in said Principal Application Specific Integrated Circuit Central Processing Unit, and

   (c) said step of Claim 6(c) (currently amended) of optimally locating said Surface Detection Units to maximize said Likelihood of Accuracy is implemented analytically in said Principal Application Specific Integrated Circuit Central Processing Unit.